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Photography — Digital still cameras — Determination of exposure index, ISO speed ratings, standard output sensitivity, and recommended exposure index

Photographie — Appareils de prises de vue numériques — Détermination de l'indice d'exposition, des régimes de vitesse ISO, de la sensibilité normale de sortie et de l'indice d'exposition recommandé

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 42, *Photography*.

This third edition cancels and replaces the second edition (ISO 12232:2006), which has been technically revised.

The main changes compared to the previous edition are as follows:

— definitions of photographic sensitivity and sensitivity setting were added;

— Clause 4 was simplified and clarified;

— it has been defined how to determine the exposure saturation level in 6.2;

— the applicability of SOS values for scene-dependent rendering and raw files was clarified;

— original Table 1 was expanded to include higher values, and separated the SOS and REI columns into a new Table 2, which includes alternate values for some of the rows;

— Annex B was updated to clarify the mathematical basis of Formula (2);

— Annex E was cancelled.

Introduction

The exposure index (EI), ISO speed ratings, standard output sensitivity (SOS) and recommended exposure index (REI) are useful metrics related to the capture of digital images. Standardization assists users and manufacturers in determining the capabilities of Digital Still Cameras (DSCs), in setting DSCs appropriately for the capture conditions, in obtaining well-exposed images, and in communicating exposures and the related DSC characteristics in image files.

The exposures produced by a DSC are determined by the exposure time, the lens aperture, the lens transmittance, the lens illumination falloff, the flare light present at the sensor, and the level and spectral distribution of the scene radiances incident on the camera lens. However, it is not typical for users to deal with this degree of complexity when determining and specifying image exposures. To provide a means for simply communicating exposure information, this document specifies an exposure index (EI) that corresponds to the focal plane exposure of a typical mid-tone. It is intended to be used for setting the camera exposure and as a record of the camera exposure in image files.

When an image from a DSC is obtained using an insufficient exposure, proper tone reproduction can generally be maintained by increasing the electronic or digital gain, but the image will contain an unacceptable amount of noise. As the exposure is increased, the gain can be decreased, and, therefore, the image noise can normally be reduced to an acceptable level. If the exposure is increased excessively, the resulting signal in bright areas of the image may exceed the maximum signal level capacity of the image sensor or camera signal processing. This can cause the image highlights to be clipped to form a uniformly bright area, or to bloom into surrounding areas of the image. Therefore, it is important to know the EI that will on-average produce the best image quality for specific DSC settings, and the range of EIs over which the DSC can be expected to produce acceptable image quality. The ISO speed and speed latitude ratings are intended to provide such information.

This document was designed to harmonize with earlier standards developed for film-based photography. For example, the equations were chosen so that using a particular EI on a DSC should result in approximately the same camera exposure settings, and resulting focal plane exposures, as would be obtained using the same EI on a photographic film camera. For example, the value of 10 as the constant in Formula (1) of this document is consistent with ISO 2721, so as to harmonize with this earlier ISO standard for photographic film cameras. ISO 2721 uses the term nominal exposure and assumes that the nominal exposure is an arithmetic mean exposure value, which usually corresponds to the mid-tone in photographs of average scenes.

However, there are differences between electronic and film-based imaging systems that preclude exact equivalency. DSCs can include variable gain and can provide digital processing after the image data has been captured, enabling desired tone reproduction to be achieved over a range of camera exposures. It is therefore possible for DSCs to have a range of ISO speed ratings. This range is defined as the ISO speed latitude. To prevent confusion, a single value is designated as the ISO speed, with the ISO speed latitude upper and lower limits indicating the speed range.

It can also be useful to compare or record the sensitivity of a DSC, for cases where the DSC has a fixed sensitivity. The standard output sensitivity (SOS) is designed to meet this need. Likewise, it can be useful to know the EI recommended by the DSC manufacturer for a specific condition. This information is provided by the recommended exposure index (REI).

Photography — Digital still cameras — Determination of exposure index, ISO speed ratings, standard output sensitivity, and recommended exposure index

1 Scope

This document specifies the method for assigning and reporting ISO speed ratings, ISO speed latitude ratings, standard output sensitivity values, and recommended exposure index values, for digital still cameras. It is applicable to both monochrome and colour digital still cameras.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7589:2002, *Photography — Illuminants for sensitometry — Specifications for daylight, incandescent tungsten and printer*

ISO 14524, *Photography — Electronic still-picture cameras — Methods for measuring opto-electronic conversion functions (OECFs)*

ITU-R BT.709, *Parameter values for the HDTV standards for production and international programme exchange*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
digital still camera
DSC
device which incorporates an image sensor and which produces digital image data representing a still picture

Note 1 to entry: A digital still camera is typically a portable, hand-held device. The device can provide additional functions, for example video image capture or wireless telephony. The digital image data is usually recorded on a removable memory, such as a solid-state memory card or using internal memory.

3.2
DSC image signal
image data stored or output by a digital still camera

3.3
exposure index
EI
numerical value that is inversely proportional to the exposure provided to an image sensor to obtain an image

Note 1 to entry: Images obtained from a DSC using a range of exposure index values will normally provide a range of image quality levels.

3.4
exposure saturation
minimum focal plane exposure that produces the maximum valid (not clipped or bloomed) DSC image signal

Note 1 to entry: The exposure saturation is expressed in lux-seconds (lx·s).

3.5
exposure series
series of images of the same subject taken using different exposure index values

3.6
image sensor
electronic device that converts incident electromagnetic radiation into an electronic signal

EXAMPLE A charge coupled device (CCD) array or a CMOS image array.

3.7
ISO speed
numerical value calculated from the exposure provided at the focal plane of a DSC to produce specified DSC image signal characteristics

Note 1 to entry: The ISO speed is usually the highest exposure index value that still provides peak image quality for normal scenes. However, a DSC does not necessarily use the ISO speed value as the exposure index value when capturing images.

3.8
ISO speed latitude
set of two numerical values calculated from the exposure provided at the focal plane of a DSC to produce specified DSC image signal characteristics

Note 1 to entry: The ISO speed latitude is expected to correlate with the range of exposure index values that provide acceptable image quality for normal scenes.

3.9
photographic sensitivity
general term used for numerical values calculated based on the exposure at the focal plane of a DSC which produces a specified DSC image signal level, such as the standard output sensitivity or recommended exposure index

Note 1 to entry: In practise, the photographic sensitivity is often called the "sensitivity" or the "camera sensitivity". It is sometimes called the “ISO sensitivity”, for historical reasons that date from ISO standards for photographic film cameras.

3.10
photosite integration time
total time period during which the photosites of an image sensor are able to integrate the light from the scene to form an image

3.11
recommended exposure index
REI
specific exposure index value recommended by a DSC provider as a reference for adjusting photographic accessories

Note 1 to entry: REI provides a practical exposure index value for setting the reference exposure index of light meters, studio lighting, etc., but images taken using this exposure index value do not necessarily provide the best image quality.

3.12
signal processing
operations performed by electronic circuits or algorithms that convert or modify the output of an image sensor

3.13
sensitivity setting
numerical value of the photographic sensitivity used by a DSC when capturing images

Note 1 to entry: In some cases the sensitivity setting is set by the user. In other cases it is set automatically by the DSC.

Note 2 to entry: In DSCs employing an automatic exposure control system, the difference between the EI value used to capture an image and the sensitivity setting is called the “exposure bias”. The value of the exposure bias is typically indicated using EV (exposure value) units.

Note 3 to entry: For historical reasons, the sensitivity setting of a DSC is often labelled the "ISO".

3.14
standard output sensitivity
SOS
specific exposure index value for a DSC that provides a still image with a specified DSC image signal value under specified test conditions

Note 1 to entry: SOS provides a practical exposure index value based on the signal level of images captured with a DSC, but images taken using this exposure index value do not necessarily provide the best image quality.

4 Exposure index

4.1 General

An exposure index (EI) is a numerical value that is inversely proportional to the exposure provided to an image sensor to obtain an image. Images obtained from a DSC using a range of EI values will normally provide a range of image quality levels. The photographic sensitivity of a DSC is a particular EI value calculated from the exposure provided at the focal plane of the DSC that produces a specified camera image signal level.

The EI value I_{EI} for a specific image captured by a DSC shall be equal to the EI reference exposure of 10 lx·s divided by the focal plane exposure used to capture the image, as specified in Formula (1):

$$I_{\mathrm{EI}} = K/H_{\mathrm{m}} \tag{1}$$

where

K is a constant equal to 10 lx·s and

H_{m} is the average focal plane exposure, expressed in lx·s.

NOTE 1 For an average scene, the average focal plane exposure is a mid-tone exposure, which is approximately equal to the exposure which would be obtained from an 18 % reflectance test card positioned in the scene and illuminated by the main light source.

In the case where the image recorded by the camera is the result of processing that combines multiple captured images, the EI value corresponds to the sum of the exposures for the images that have been combined. In this case, the EI value should be reported along with a notation indicating that multiple images have been combined.

EI values should be reported using exposure index metadata in the image file header. In the case where multiple captured images have been combined, the number of captured images that were combined and the EI values for the individual captured images should also be reported using metadata.

4.2 Focal plane measurement

For DSCs where it is possible to measure the focal plane exposure directly, such as a DSC with a removable lens, the value of H_m should be measured using spatially uniform and spectrally neutral illumination. The measurement should be made within a circle lying in the centre of the focal plane with a diameter of 75/100 times the shorter dimension of the image field.

4.3 Estimating focal plane exposure from scene luminance

For DSCs where it is not practical to measure the focal plane exposure, the value of H_m required in Formula (1) should be estimated using Formula (2). The measurement should be made using a test card for a flat-field image (i.e. a spatially uniform field-of-view of spectrally neutral reflectance) at a distance of at least one meter, using only the portion of the field of view of the image sensor that is subtended by an angle of less than 10°. If the lens focus can be manually adjusted, it should be set to the infinity position. The derivation of Formula (2) is given in Annex B.

$$H_\mathrm{m} = \frac{65 L_a t}{100 A^2} \tag{2}$$

where

A is the f-number of the lens;

L_a is the luminance, expressed in candelas per square metre, measured using a full frame uniformly illuminated diffuse reflecting test card (i.e. a spatially uniform field-of-view of spectrally neutral reflectance);

t is the photosite integration time, expressed in seconds.

5 Test conditions

5.1 General

The following measurement conditions should be used as nominal conditions when determining the ISO speed ratings, SOS, and REI values of a DSC. If it is not possible or not appropriate to use these nominal operating conditions, the actual operating conditions shall be listed along with the reported values.

5.2 Illumination

The reported values shall indicate whether illumination approximating the ISO 7589 daylight or studio tungsten illuminant was used. ISO 7589 describes the procedures for determining if the illumination used in a specific speed rating determination test is an acceptable match to the daylight and studio tungsten illuminants. Also, the spectral power distribution of the illumination used should be reasonably similar to that of the ISO 7589 daylight or studio tungsten reference illuminant.

5.2.1 Daylight reference illuminant

For daylight measurements without the camera lens, the ISO sensitometric daylight illuminant given in ISO 7589:2002, Table 1, shall be used. This illuminant is defined as the product of the spectral power distribution of CIE colorimetric standard illuminant D_{55} and the spectral transmittance of the International Standard camera lens. For measurements with the camera lens in place, the spectral radiance characteristics of the light used for the measurement should be equivalent to the daylight ISO standard source provided in the second column of ISO 7589:2002, Table 1. In order to apply the ISO SDI (spectral distribution index) criterion, the spectral radiance of the light shall be measured and then multiplied by the relative spectral transmittance of the ISO standard lens, which is also described in ISO 7589, prior to multiplying by the weighted spectral sensitivities.

5.2.2 Tungsten reference illuminant

For tungsten measurements without the camera lens, the ISO sensitometric studio tungsten illuminant given in ISO 7589:2002, Table 2, shall be used. This illuminant is defined as the product of the average spectral power distribution of experimentally measured sources having a colour temperature of approximately 3 050 K and the spectral transmittance of the International Standard camera lens. For measurements with the camera lens in place, the spectral radiance characteristics of the light used for the measurement should be equivalent to the tungsten ISO standard source provided in the second column of ISO 7589:2002, Table 2. In order to apply the ISO SDI (spectral distribution index) criterion, the spectral radiance of the light shall be measured and then multiplied by the relative spectral transmittance of the ISO standard lens, which is also described in ISO 7589, prior to multiplying by the weighted spectral sensitivities.

5.3 Temperature and relative humidity

The ambient temperature during the acquisition of the test data shall be (23 ± 2) °C and the relative humidity should be (50 ± 20) %.

5.4 White balance

For a colour camera, the camera white balance should be adjusted, if possible, to provide proper white balance (equal RGB signal levels) for the illumination light source, as specified in ISO 14524.

5.5 Infrared (IR) blocking filter

If required, an infrared (IR) blocking filter shall be used as specified in ISO 14524.

5.6 Photosite integration time

The photosite integration time should not be longer than 1/30 s.

5.7 Compression

If the DSC includes any form of lossy compression, the compression shall be disabled, if possible, during the determination of $\sigma(D_\mathrm{H})$ or $\sigma(D_\mathrm{L})$ in Clause 6. If it is not possible to disable the camera compression, the noise-based values cannot be properly determined, and shall not be reported.

5.8 Other DSC user settings

All other camera controls (e.g. sharpness, contrast) shall be set to the factory default settings. Additional, optional, measurements can also be made using camera control settings that are not the factory default settings. However, the reporting of such optional measurements shall be done in a manner that does not cause confusion with the primary measurements made using the factory default settings.

6 Determination of ISO speed and ISO speed latitude

6.1 General

With appropriate electrical or digital gain, a DSC can provide an appropriate DSC image signal level for a range of sensor exposure levels. The maximum exposure level is just below the exposure level where typical picture highlights will be clipped as a result of saturating the image sensor's signal capacity or reaching the camera signal processing's maximum signal level. The minimum exposure level relates to the amount of noise that can be tolerated in the image. These situations lead to two different types of speed value calculations: those based on saturation exposure, and those based on mid-tone noise characteristics. If the DSC provides an adequate dynamic range, the ISO speed is determined using a noise-based calculation and the saturation-based calculation is used to determine the camera's overexposure latitude. A second noise-based calculation is used to determine the camera's underexposure latitude.

For some types of DSCs, such as those employing lossy compression methods, it is not possible to correctly determine the mid-tone noise characteristics. In such cases, the ISO speed of the camera is determined using the saturation-based calculation, and the ISO speed latitude values are not reported. In other cases, the noise-based values may be lower than the saturation-based values, in which case the saturation based value is reported.

ISO speed and ISO speed latitude values may be reported for either scene-referred or output-referred images. ISO speed and ISO speed latitude values shall not be reported for raw images, however, because with raw images processing that affects the values has not been performed.

6.2 Saturation-based calculations

In photographic applications where the scene illumination level can be controlled, for example in studio photography, the photographer normally prefers to use an exposure index which provides the best possible image quality. In this situation, setting the exposure index based on the value determined using a saturation exposure based calculation is appropriate. This allows the user to set the camera exposure so that typical image highlights are just below the maximum possible (saturation) DSC image signal value.

6.2.1 Focal plane measurement

The saturation based value, I_{SAT}, of an electronic still picture camera is defined as:

$$I_{sat} = K_s / H_{sat} \tag{3}$$

where

K_s is a constant equal to 78 lx-s;

H_{SAT} is the exposure saturation level, expressed in lux-seconds (lx·s).

NOTE 1 The value of K_s in Formula (3) is larger than the value of K in Formula (1) because H_a in Formula (1) is a mid-tone exposure while H_{sat} is a highlight exposure.

NOTE 2 The value of K_s in Formula (3) provides 1/2 “stop" of headroom (41 % additional headroom) for specular highlights above the DSC image signal level that would be obtained from a theoretical 100 % reflectance object in the scene, such that a theoretical 141 % reflectance object in the scene would produce a focal plane exposure of H_{sat}.

The exposure saturation level shall be the lowest exposure level, such that less than 50 % of the pixels in a uniformly exposed region of interest (ROI) increase in digital value, when the exposure level is increased by an incremental step.

The incremental step shall increase the exposure level by no more than 26 % (0,333 step) and should increase the exposure level by no more than 10 % (0,137 step).

The ROI shall be 64 × 64 pixels, as defined in ISO 14524.

NOTE When the exposure levels are controlled by the DSC, it is preferable that the exposure level is mainly controlled by adjusting the shutter speed, while the f-number of the lens remains the same.

6.2.2 Scene luminance measurement

If the focal plane exposure of the DSC cannot be measured directly, it shall be estimated from the scene luminance measurement using Formula (2).

6.3 Noise-based calculations

In many photographic applications, it is desirable to use the highest exposure index (i.e. the lowest exposure) possible, in order to maximize the depth of field, minimize the exposure time, and offer the maximum acceptable latitude for exposure of image highlights. However, using an excessively high exposure index can result in an unacceptably noisy image. Noise-based calculations use the mid-tone exposure that provides an appropriately low noise image for a typical DSC. The mid-tone exposure value $H_{S/N40}$ is based on an objective correlation to subjective judgements of the acceptability of various noise levels in exposure series images and provides the “first excellent” image. A lower mid-tone exposure value, $H_{S/N10}$, provides the “first acceptable” image, and is used to determine the ISO speed latitude upper limit.

6.3.1 Focal plane method

The two noise-based values of a DSC, $I_{S/N40}$ and $I_{S/N10}$, shall be determined from the focal plane exposure required to produce specific image incremental signal-to-noise (S/N) ratio values for a flat-field image, measured using linearized output signals from the DSC, using the following equations (see NOTE 1):

$$I_{S/N40} = \mathrm{K}/H_{S/N40} \tag{4}$$

$$I_{S/N10} = \mathrm{K}/H_{S/N10} \tag{5}$$

where $H_{S/N40}$ is the exposure that provides DSC image signals which, when linearized, satisfy the equation:

$$D = 40\,\sigma(D) \tag{6}$$

K is a constant equal to 10 lx·s, and $H_{S/N10}$ is the exposure that provides DSC image signals which, when linearized, satisfy Formula (7):

$$D = 10\,\sigma(D) \tag{7}$$

where

D is the linearized luminance signal level;

H is the input exposure, in lux-seconds, needed to produce the linearized luminance signal level D;

$\sigma(D)$ is the standard deviation of the linearized monochrome output level values at the linearized signal level D (for monochrome cameras) or standard deviation of the linearized, weighted colour DSC output values (for colour cameras, as provided in 6.3.3), taken from a 64 by 64 pixel area (see NOTE 2).

The DSC image signals shall be linearized in accordance with ISO 14524 and the linearized values shall be filtered using the filter provided in Annex D prior to determining $\sigma(D)$.

The value of H in Formulae (4) and (5) may be determined using the procedure described in Annex A.

NOTE 1 The value of K that appears in the numerator of Formulae (4) and (5) places the exposures associated with the respective signal-to-noise ratios at a mid-tone exposure, which is approximately equal to the exposure that would be obtained from an 18 % reflectance value in a 160:1 contrast-ratio scene.

NOTE 2 If there is not a significant effect on the resulting S/N, a smaller or larger area is allowable.

NOTE 3 The S/N values of 40 for the “first excellent” image and 10 for the “first acceptable” image were determined using subjective experiments performed during the development of this document. These incremental signal-to-noise ratios were judged to provide “excellent” and “acceptable” quality prints of typical pictorial images using a high quality printer at approximately 70 sensor pixels/cm on the print (just small enough to be visually imperceptible) using normal tone reproduction. Note that 70 pixels/cm at a standard viewing distance of 25 cm corresponds to 30 pixels per degree of visual subtense. For prints made using significantly higher sensor pixels per centimetre values, lower S/N values can still yield acceptably low noise prints, while for prints made using significantly lower sensor pixels per centimetre values, higher S/N values can be required to provide acceptably low noise prints. In these cases, the S/N value for “excellent” quality prints is approximately equal to $(70/P)$ times the S/N values listed, where P is the actual number of sensor pixels per centimetre on the print.

6.3.2 Scene luminance method

If the focal plane exposure of the DSC cannot be measured directly, it shall be computed from the scene luminance using Formula (2).

6.3.3 Colour cameras

The noise of the luminance and colour difference signals shall be determined from CRT display output-referred RGB colour signals based on the ITU-R BT.709 RGB primaries and white point, such as the sRGB and sYCC signals defined in IEC 61966-2-1, which are used as DSC image signals in many DSCs.

For colour cameras using a single exposure process, $\sigma(D)$ shall be determined using the linearized DSC image signals. If the DSC provides CRT display output-referred RGB colour signals based on the ITU R BT.709 primaries and white point, these signals shall be converted to linearized RGB signals in accordance with ISO 14524. If the DSC encodes these RGB signals as Y, Cr, Cb image signals, the signals shall be decoded to provide RGB image signals using the inverse of the matrix used to encode the signals. The decoded RGB image signals shall then be converted to linearized RGB signals in accordance with ISO 14524.

If the DSC image signals are not CRT display output-referred RGB colour signals based on the ITU R BT.709 primaries and white point, they shall be converted to the required signals, using an appropriate colour space conversion and rendering process if necessary, prior to performing the noise analysis.

The linearized luminance signal shall be formed from the linearized RGB signals using Formula (8):

$$Y = \left(2\,126/10\,000\,R\right) + \left(7\,152/10\,000\,G\right) + \left(722/10\,000\,B\right) \tag{8}$$

The value of the camera noise, $\sigma(D)$ shall be computed using Formula (9):

$$\sigma(D) = \left\{ \sigma(Y)^2 + \left[279\big/1\,000\,\sigma(R-Y)^2 \right] + \left[88\big/1\,000\,\sigma(B-Y)^2 \right] \right\}^{1/2} \tag{9}$$

6.3.4 Quantization effects

If the DSC has quantization steps which are similar in magnitude to, or larger than, the measured standard deviation, quantization effects may result in the measured standard deviation being incorrect. This type of error may be corrected to some extent by repeated measurements on different image files, but if the actual standard deviation is small, even repeated measurements may result in the value determined being too low. To compensate for this effect, the value of $\sigma(D)$ used in Formulae (6) and (7) shall be not less than 1/2.

NOTE The value of 1/2 is greater than the standard deviation of noise from uniform quantization, which equals the square-root of 1/12. The value of 1/2 has been chosen because if the measured standard deviation is below this value, the measured values are significantly influenced by quantization effects and are no longer meaningful.

6.4 Method of reporting

The ISO speed of a DSC shall be denoted “ISO xxx D” (or alternatively “ISO xxx”) for daylight illumination and “ISO xxx T” for tungsten illumination. If $I_{S/N40}$ is higher than I_{sat}, the reported number “xxx” shall be the value from the third column of Table 1 from the same row as the $I_{S/N40}$ value (in the second column of Table 1) determined in 6.2. The ISO speed latitude shall be denoted “ISO Speed Latitude yyy – zzz D” (or alternatively “ISO Speed Latitude yyy – zzz:”) for daylight illumination and “ISO Speed Latitude yyy – zzz T” for tungsten illumination. The reported number “yyy” shall be the value from the third column of Table 1 from the same row as the I_{sat} value (in the first column of Table 1) determined in 6.1. The reported number “zzz” shall be the value from the third column of Table 1 from the same row as the $I_{S/N10}$ value determined in 6.2.

If $I_{S/N40}$ is lower than I_{sat}, or if $I_{S/N40}$ cannot be determined because the noise level of the camera does not allow for a $S/N = 40$ value, the ISO speed of the camera shall be denoted “ISO yyy D” (or alternatively “ISO yyy”) for daylight illumination and “ISO yyy T” for tungsten illumination, where “yyy” is the speed rating from Table 1 corresponding to the saturation based value determined in 6.2. The reported number “yyy” shall be the value from the third column of Table 1 from the same row as the I_{sat} value (in the first column of Table 1) determined in 6.2. The ISO speed latitude shall be denoted as described in the preceding paragraph, unless the $I_{S/N10}$ value is lower than the I_{sat} value, or the noise level of the camera does not allow for a $S/N = 10$ value, in which case an ISO speed latitude shall not be reported.

The ISO speed reported in image file headers shall conform to the reporting requirements outlined above.

Table 1 — ISO speed and ISO speed latitude reported values

I_{sat} **(from 6.2)**	$I_{\text{S/N}}$ **(from 6.3)**	**Reported value**
$8 < I_{\text{sat}} < 10$	$10 < I_{S/N} < 12$	10
$10 < I_{\text{sat}} < 12$	$12 < I_{S/N} < 16$	12
$12 < I_{\text{sat}} < 16$	$16 < I_{S/N} < 20$	16
$16 < I_{\text{sat}} < 20$	$20 < I_{S/N} < 25$	20
$20 < I_{\text{sat}} < 25$	$25 < I_{S/N} < 32$	25
$25 < I_{\text{sat}} < 32$	$32 < I_{S/N} < 40$	32
$32 < I_{\text{sat}} < 40$	$40 < I_{S/N} < 50$	40
$40 < I_{\text{sat}} < 50$	$50 < I_{S/N} < 64$	50
$50 < I_{\text{sat}} < 64$	$64 < I_{S/N} < 80$	64
$64 < I_{\text{sat}} < 80$	$80 < I_{S/N} < 100$	80
$80 < I_{\text{sat}} < 100$	$100 < I_{S/N} < 125$	100
$100 < I_{\text{sat}} < 125$	$125 < I_{S/N} < 160$	125
$125 < I_{\text{sat}} < 160$	$160 < I_{S/N} < 200$	160
$160 < I_{\text{sat}} < 200$	$200 < I_{S/N} < 250$	200
$200 < I_{\text{sat}} < 250$	$250 < I_{S/N} < 320$	250
$250 < I_{\text{sat}} < 320$	$320 < I_{S/N} < 400$	320
$320 < I_{\text{sat}} < 400$	$400 < I_{S/N} < 500$	400
$400 < I_{\text{sat}} < 500$	$500 < I_{S/N} < 640$	500

Table 1 *(continued)*

I_{sat} **(from 6.2)**	$I_{S/N}$ **(from 6.3)**	**Reported value**
500 < I_{sat} < 640	640 < $I_{S/N}$ < 800	640
640 < I_{sat} < 800	800 < $I_{S/N}$ < 1 000	800
800 < I_{sat} < 1 000	1 000 < $I_{S/N}$ < 1 250	1 000
1 000 <I_{sat} < 1 250	1 250 < $I_{S/N}$ < 1 600	1 250
1 250 < I_{sat} < 1 600	1 600 < $I_{S/N}$ < 2 000	1 600
1 600 < I_{sat} < 2 000	2 000 < $I_{S/N}$ < 2 500	2 000
2 000 < I_{sat} < 2 500	2 500 < $I_{S/N}$ < 3 200	2 500
2 500 < I_{sat} < 3 200	3 200 < $I_{S/N}$ < 4 000	3 200
3 200 < I_{sat} < 4 000	4 000 < $I_{S/N}$ < 5 000	4 000
4 000 < I_{sat} < 5 000	5 000 < $I_{S/N}$ < 6 400	5 000
5 000 < I_{sat} < 6 400	6 400 < $I_{S/N}$ < 8 000	6 400
6 400 < I_{sat} < 8 000	8 000 < $I_{S/N}$ < 10 000	8 000
8 000 < I_{sat} < 10 000	10 000 < $I_{S/N}$ < 12 500	10 000
10 000 <I_{sat} < 12 500	12 500 < $I_{S/N}$ < 16 000	12 500
12 500 < I_{sat} < 16 000	16 000 < $I_{S/N}$ < 20 000	16 000
16 000 < I_{sat} < 20 000	20 000 < $I_{S/N}$ < 25 000	20 000
20 000 < I_{sat} < 25 000	25 000 < $I_{S/N}$ < 32 000	25 000
25 000 < I_{sat} < 32 000	32 000 < $I_{S/N}$ < 40 000	32 000
32 000 < I_{sat} < 40 000	40 000 < $I_{S/N}$ < 50 000	40 000
40 000 < I_{sat} < 50 000	50 000 < $I_{S/N}$ < 64 000	50 000
50 000 < I_{sat} < 64 000	64 000 < $I_{S/N}$ < 80 000	64 000
64 000 < I_{sat} < 80 000	80 000 < $I_{S/N}$ < 100 000	80 000
80 000 < I_{sat} < 100 000	100 000 < $I_{S/N}$ < 125 000	100 000
100 000 <I_{sat} < 125 000	125 000 < $I_{S/N}$ < 160 000	125 000
125 000 < I_{sat} < 160 000	160 000 < $I_{S/N}$ < 200 000	160 000
160 000 < I_{sat} < 200 000	200 000 < $I_{S/N}$ < 250 000	200 000
200 000 < I_{sat} < 250 000	250 000 < $I_{S/N}$ < 320 000	250 000
250 000 < I_{sat} < 320 000	320 000 < $I_{S/N}$ < 400 000	320 000
320 000 < I_{sat} < 400 000	400 000 < $I_{S/N}$ < 500 000	400 000
400 000 < I_{sat} < 500 000	500 000 < $I_{S/N}$ < 640 000	500 000
500 000 < I_{sat} < 640 000	640 000 < $I_{S/N}$ < 800 000	640 000
640 000 < I_{sat} < 800 000	800 000 < $I_{S/N}$ <1 000 000	800 000
800 000 < I_{sat} < 1 000 000	1 000 000 < $I_{S/N}$ < 1 250 000	1 000 000
1 000 000 <I_{sat} < 1 250 000	1 250 000 < $I_{S/N}$ < 1 600 000	1 250 000
1 250 000 < I_{sat} < 1 600 000	1 600 000 < $I_{S/N}$ < 2 000 000	1 600 000
1 600 000 < I_{sat} < 2 000 000	2 000 000 < $I_{S/N}$ < 2 500 000	2 000 000
2 000 000 < I_{sat} < 2 500 000	2 500 000 < $I_{S/N}$ < 3 200 000	2 500 000
2 500 000 < I_{sat} < 3 200 000	3 200 000 < $I_{S/N}$ < 4 000 000	3 200 000
3 200 000 < I_{sat} < 4 000 000	4 000 000 < $I_{S/N}$ < 5 000 000	4 000 000
4 000 000 < I_{sat} < 5 000 000	5 000 000 < $I_{S/N}$ < 6 400 000	5 000 000

Table 1 *(continued)*

I_{sat} **(from 6.2)**	$I_{S/N}$ **(from 6.3)**	**Reported value**
5 000 000 < I_{sat} < 6 400 000	6 400 000 < $I_{S/N}$ < 8 000 000	6 400 000
6 400 000 < I_{sat} < 8 000 000	8 000 000 < $I_{S/N}$ <10 000 000	8 000 000
8 000 000 < I_{sat} < 10 000 000	10 000 000 < $I_{S/N}$ < 12 500 000	10 000 000

NOTE Rounding of EI values is not specified.

7 Determination of standard output sensitivity (SOS)

The “standard output sensitivity” (SOS) is the exposure index value (I_{SOS}) for a DSC that provides a still image with a specified DSC image signal value under specified test conditions.

Since the SOS value varies along with the DSC ISO sensitivity setting, the SOS should be determined for a fixed sensitivity setting. When the DSC uses an automatic variable sensitivity mode, the SOS may be reported as “variable”, or the range of the SOS values may be reported. Furthermore, the image rendering processing applied in some DSCs can be scene-dependent and can result in a variable SOS even when the DSC is set on a fixed sensitivity. When this is the case, the SOS may be reported as "variable" or the range of the SOS values may be reported. Changing the colour encoding output by the DSC can also change the SOS. It is generally not appropriate to report SOS values for raw files, since the SOS value will depend on the subsequent processing of the files.

Regardless of the sensitivity mode of the DSC, the SOS value applicable when the image is captured may be reported as the SOS value accompanying the recorded image, which can be attached as metadata in the recorded image file.

7.1 Method for calculating SOS

The SOS (I_{SOS}) shall be computed using the following Formula:

$$I_{SOS} = K/H_{SOS} \tag{10}$$

where

K is a constant equal to 10 lx·s and

H_{SOS} is the exposure required to produce the specified standard level DSC image signal equal to

$$461/1\,000 \times O_{MAX} \tag{11}$$

where O_{MAX} is the maximum output value of the digital system. For 8-bit systems, the reference level shall be 118.

NOTE The code value of 118 in an 8-bit system corresponds to 18 % of the maximum final output for sRGB.

The test conditions shall be as specified in Clause 5. Recommendations for determining I_{SOS} values are provided in Annex C. If a camera OECF chart is used to determine SOS values, the illumination level should be 2 000 lx at the chart surface for reflection test charts, and 637 cd/m^2 for the most transparent portions of transparency charts.

If the DSC includes a user controlled sensitivity setting, it shall be set to one or more specific levels, which shall be reported along with the measurement results.

7.2 Method of reporting

The value calculated using Formula (10) shall be rounded off using Table 2 and reported as the "Standard Output Sensitivity (I_{SOS}). A "D" or descriptive term such as "Daylight" can be used to designate daylight illumination, but is not required. A "T" or descriptive term such as "Tungsten" shall be used to designate tungsten illumination. An example of acceptable reporting is as follows:

ISO sss (SOS/Daylight)

where "sss" is the reported value from the second column in Table 2.

It is possible that the I_{SOS} value changes as a function of the *f*-number of the lens, for example due to the structure of a microlens overlay on the image sensor. In such cases, the *f*-number used for the measurement shall be reported along with the I_{SOS} value.

8 Specification of recommended exposure index (REI)

8.1 General

The DSC recommended exposure index (I_{REI}) is a numerical value that is recommended by the DSC provider as a reference. The I_{REI} can be used to provide appropriate settings for photographic accessories, such as exposure meters and strobe lights.

When the DSC includes a manual exposure mode or includes an exposure mode using a simple automatic exposure function, then the I_{REI} value is useful. However, when the DSC includes only a sophisticated automatic exposure function, which adjusts the exposure level based on the subject pattern or the absolute luminance range in the scene, the I_{REI} value in not useful and should not be reported.

8.2 Method for calculating recommended exposure index

The DSC recommended exposure index shall be computed using the following Formula (12):

$$I_{REI} = \mathrm{K}/H_m \tag{12}$$

where

K is a constant equal to 10 lx·s;

H_m is the arithmetic mean focal plane exposure, expressed in lux-seconds, recommended by the DSC provider.

If the recommended exposure index varies as a function of camera mode settings or environmental conditions, these factors shall be reported. Unless otherwise indicated, the default camera mode settings and the environmental settings provided in Clause 5 shall be used.

The I_{REI} should be reported for both daylight and tungsten illumination.

8.3 Method of reporting

The value calculated using Formula (12) shall be rounded off using Table 2 and reported as the "recommended exposure index" (I_{REI}). A "D" or descriptive term such as "Daylight" can be used to designate daylight illumination, but is not required. A "T" or descriptive term such as "Tungsten" shall be used to designate tungsten illumination. An example of acceptable reporting is as follows:

ISO rrr (REI/Daylight)

where "rrr" is the reported value from the second column in Table 2.

Table 2 — I_{SOS} and I_{REI} reported values

x is the measured value of I_{SOS} and I_{REI}	Reported value
8,909 < *x* < 11,22	10
11,22 < *x* < 14,14	12
14,14 < *x* < 17,82	16
17,82 < *x* < 22,45	20
22,45 < *x* < 28,28	25
28,28 < *x* < 35,64	32
35,64 < *x* < 44,90	40
44,90 < *x* < 56,57	50
56,57 < *x* < 71,27	64
71,27 < *x* < 89,09	80
89,09 < *x* < 112,2	100
112,2 < *x* < 141,4	125
141,4 < *x* < 178,2	160
178,2 < *x* < 224,5	200
224,5 < *x* < 282,8	250
282,8 < *x* < 356,4	320
356,4 < *x* < 449,0	400
449,0 < *x* < 565,7	500
565,7 < *x* < 712,7	640
712,7 < *x* < 890,9	800
890,9 < *x* < 1 122	1 000
1 122 < *x* < 1 414	1 250
1 414 < *x* < 1 782	1 600
1 782 < *x* < 2 245	2 000
2 245 < *x* < 2 828	2 500
2 828 < *x* < 3 564	3 200
3 564 < *x* < 4 490	4 000
4 490 < *x* < 5 657	5 000
5 657 < *x* < 7 127	6 400
7 127 < *x* < 8 909	8 000
909 < *x* < 11 220	10 000
11 220 < *x* < 14 140	12 500 or 12 800
14 140 < *x* < 17 820	16 000
17 820 < *x* < 22 450	20 000
22 450 < *x* < 28 280	25 000 or 25 600
28 280 < *x* < 35 640	32 000
35 640 < *x* < 44 900	40 000
44 900 < *x* < 56 570	50 000 or 51 200
56 570 < *x* < 71 270	64 000
71 270 < *x* < 89 090	80 000
89 090 < *x* < 112 200	100 000 or 102 400
112 200 < *x* < 141 400	125 000 or 128 000
141 400 < *x* < 178 200	160 000

Table 2 *(continued)*

***x* is the measured value of I_{SOS} and I_{REI}**	**Reported value**
178 200 < *x* < 224 500	200 000 or 204 800
224 500 < *x* < 282 800	250 000 or 256 000
282 800 < *x* < 356 400	320 000
356 400 < *x* < 449 000	400 000 or 409 600
449 000 < *x* < 565 700	500 000 or 512 000
565 700 < *x* < 712 700	640 000
712 700 < *x* < 890 900	800 000 or 819 200
890 900 < *x* < 1 122 000	1 000 000 or 1 024 000
1 122 000 < *x* < 1 414 000	1 250 000 or 1 280 000
1 414 000 < *x* < 1 782 000	1 600 000
1 782 000 < *x* < 2 245 000	2 000 000 or 2 048 000
2 245 000 < *x* < 2 828 000	2 500 000 or 2 560 000
2 828 000 < *x* < 3 564 000	3 200 000
3 564 000 < *x* < 4 490 000	4 000 000 or 4 096 000
4 490 000 < *x* < 5 657 000	5 000 000 or 5 120 000
5 657 000 < *x* < 7 127 000	6 400 000
7 127 000 < *x* < 8 909 000	8 000 000 or 8 192 000
8 909 000 < *x* < 11 220 000	10 000 000 or 10 240 000

Annex A
(informative)

Recommended procedure for determining the noise-based ISO speed

The value of H in Formulae (4) or (5) may be determined by plotting the incremental S/N as a function of H, and estimating the value that produces an incremental S/N value equal to 40 for $I_{S/N40}$ and 10 for $I_{S/N10}$.

A preferred procedure for making this determination for colour DSCs is as follows.

a) Obtain DSC output RGB values either directly, or by converting the camera's Y, Cb Cr signals to RGB signals using the inverse of the RGB to Y, Cb, Cr encoding equations.

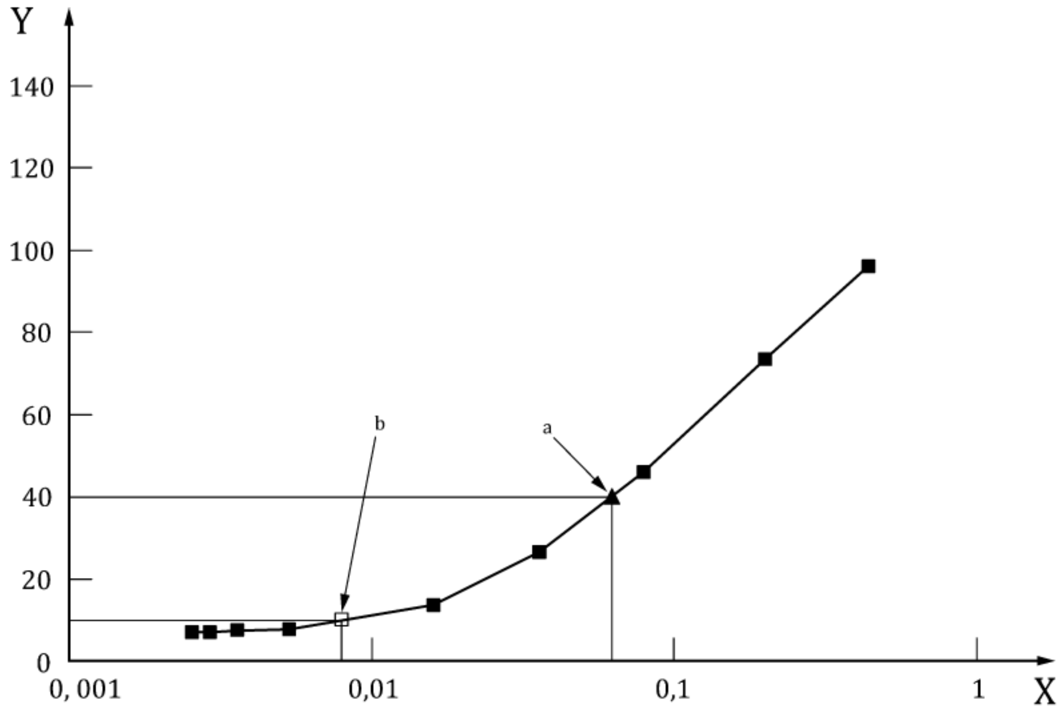
b) Determine the system OECF in accordance with ISO 14524. Focal plane OECF values are preferred, although alternative focal plane values may be used for cameras with fixed lenses, and camera OECF values may be used for cameras with fixed lenses and non-overrideable automatic exposure control. Convert the RGB DSC image signals into linearized RGB signals.

c) Calculate linearized Y, R-Y, and B-Y image data using Formula (8) to calculate Y. It is usually necessary to add an offset in calculating the R-Y, and B-Y difference channels to prevent the difference values from wrapping around zero. Wrapped values will produce incorrectly low standard deviation values.

d) Determine the standard deviation of the pixel values in each 64 by 64 area selected for the OECF measurement, using Formula (9).

e) Calculate the signal-to-noise values as a function of the exposure H. Determine the values of H that produce signal-to-noise values of 10 and 40. Use Formulae (4) and (5) to determine the ISO noise-based speeds. Use Table 1 to determine the reported value.

Figure A.1 shows an example of a logarithmic plot of the weighted colour signal-to-noise ratio (CSNR) versus exposure (H), in lux-seconds. The CSNR = 40 intercept is (68/1 000) lx·s, corresponding to an ISO speed reported value of 125. The CSNR = 10 intercept is (8/1 000) lx·s, corresponding to an ISO speed latitude upper limit reported value of 1 250.



Key

X exposure H, lx·s

Y signal-to-noise ratio, CSNR

a At CSNR = 40, H = (68/1 000) lx·s, corresponding to an ISO speed reported value of 125.

b At CSNR = 10, H = (8/1 000) lx·s, corresponding to an ISO speed latitude upper limit reported value of 1 250.

NOTE In accordance with ISO 31-0, the decimal sign is a comma.

Figure A.1 — Example plot of incremental signal-to-noise ratio versus exposure

Annex B
(informative)

Scene luminance and focal plane exposure

This annex describes the mathematical basis of Formula (2) of this document (See Reference [20]). The fundamental relationship between the scene luminance and the focal plane exposure is expressed by Formula (B.1):

$$H = \frac{Lt\pi(u-f)^2 \, T\, C\, V \cos^4(\theta)}{4\,A^2\,u^2} \tag{B.1}$$

where

H is the focal plane exposure, expressed in lux-seconds;

L is the scene luminance, expressed in candelas per square meter;

t is the exposure time, expressed in seconds;

u is the image distance, expressed in meters;

f is the lens focal length, expressed in meters;

A is the lens *f*-number;

T is the transmittance of the lens;

C is the camera flare correction factor;

V is the vignetting factor; and

θ is the angle of the image point from the axis of the lens.

The correction factors can be combined into a constant q expressed by Formula (B.2):

$$q = \frac{(u-f)^2}{u^2}\frac{\pi}{4} T\,C\,V\cos^4(\theta) \tag{B.2}$$

so that

$$H = \frac{q\,Lt}{A^2} \tag{B.3}$$

When the following values are used, q is equal to 65/100 lx/(cd/m^2) (i.e. steradians)

u = 80 f

T = 0,90

C = 1,00

θ = 10° so that $\cos^4(\theta)$ = 0,94

V = 1,0

In this case, Formula (B.1) reduces to:

$$H = \frac{65 L t}{100 A^2} \tag{B.4}$$

In practise, Formula (B.4) is used for DSCs which do not have removable lenses, and the lens focus distance is set to infinity when possible, rather than 80*f*. Since it is not possible to determine the exact values for parameters such as *V* and *T*, it is not possible to calculate the precise value of *q*. However, the value 65/100 is a close approximation to the precise value of *q* and is therefore used in Formula (B.4) to provide a standard method for estimating the approximate value of *H* in situations where it is not possible to determine an exact value.

Annex C
(informative)

Recommended procedure for determining SOS values

C.1 Measure the focal plane OECF in accordance with ISO 14524

C.1.1 If the DSC exposure settings can be set manually, the focal plane or alternative focal plane measurement methods may be used.

C.1.2 If it is not possible to disable autoexposure, but the exposure settings used are accurately reported by the DSC, the camera OECF may be measured, and the scene luminance values converted to focal plane exposure values using Formula (B.2). If this method is used, a low contrast (20:1) OECF chart is recommended to minimize the effect of flare, with the chart illumination as specified in 7.1.

C.1.3 When it is not possible to disable autoexposure, care should be taken to ensure that camera analog and digital gains are fixed, as sometimes it is difficult to distinguish between autoexposure and autogain.

C.1.4 If autogains are used, it may still be possible to determine and report the limiting SOS values.

C.2 Determine the SOS

C.2.1 Take the base ten logarithm of the focal plane exposure values.

C.2.2 Interpolate the log exposure value $\log[H_{\mathrm{SOS}}]$ at the reference level using linear interpolation between the log exposure values and the DSC output digital values.

C.2.3 Take the antilog of $\log[H_{\mathrm{SOS}}]$ and determine the $\mathrm{I}_{\mathrm{SOS}}$ using Formula (10).

Annex D
(normative)

Removing low frequency variations from the image data

When determining the noise-based ISO speed, the linearized image data shall be pre-processed to remove non-uniformities (such as lens fall-off or test chart illumination non-uniformity) before measuring the Y, R-Y and B-Y standard deviations. This shall be accomplished by applying the high pass filter specified in this annex to the Y, R-Y, and B-Y colour planes. This 13 × 13 finite impulse response (FIR) spatial filter passes all but the lowest spatial frequencies.

NOTE The lenses in many DSCs exhibit a slowly varying centre to edge intensity roll off. The high pass filter defined in this annex reduces this non-uniformity from the digital image data before measuring the noise, since the non-uniformity degrades (increases) the measured noise standard deviations and reduces the measured noise-based ISO speed.

The following 13 × 13 tap FIR filter is convolved with the Y, R-Y, and B-Y image data to remove the low frequency variations from the image data. The spatial frequency response of this FIR filter greatly attenuates the lowest image spatial frequencies, including the lens non-uniformity. Table D.1 displays the bottom-right quadrant of the 13 × 13 kernel that shall be used prior to computing $\sigma(D)$. The whole 13 × 13 kernel is defined by reflecting the bottom 6 rows about the first row, and then reflecting that result about the first column. Since the table values are redundant and symmetric, only the bottom right quadrant is specified here. Negative filter output values shall not clipped to zero prior to computing $\sigma(D)$.

Table D.1 — High pass filter kernel (lower right quadrant)

0,996 926	−0,006 470	−0,007 400	−0,006 090	−0,009 600	−0,003 820	−0,009 640
−0,006 470	−0,006 640	−0,012 230	−0,005 800	−0,007 300	−0,005 480	−0,008 930
−0,007 400	−0,012 230	−0,001 730	−0,009 890	−0,005 710	−0,007 060	−0,007 180
−0,006 090	−0,005 800	−0,009 890	−0,007 920	−0,003 560	−0,009 760	−0,003 590
−0,009 600	−0,007 300	−0,005 710	−0,003 560	−0,009 640	−0,006 540	0,000 124
−0,003 820	−0,005 480	−0,007 060	−0,009 760	−0,006 540	−0,000 440	0,000 412
−0,009 640	−0,008 930	−0,007 180	−0,003 590	0,000 124	0,000 412	−0,000 130
NOTE 1 This 13 × 13 FIR filter removes the DC component of the image, and thus the mean signal value D cannot be computed from the filter output values.						
NOTE 2 In accordance with ISO 31-0, the decimal sign is a comma.						

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